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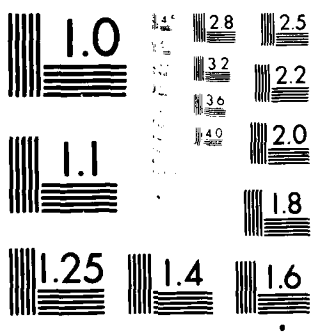

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EVENT OBSERVATION IN THE ACQUISITION OF ACOUSTIC TRANSIENT PATTERNS

James H. Howard, Jr. and James A. Ballas

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Three experiments investigated how individuals learn to classify sequentially-structured patterns of complex environmental sounds. In Experiment 1 listeners classified either auditory patterns or their visually-presented symbolic analogues as targets or nontargets. Some individuals received "observation" trials on which they simply heard (saw) examples of the target patterns prior to classification. The observation trials were shown to be effective for target acquisition,

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and positive transfer occurred between symbolic observation and subsequent auditory pattern classification. The results of Experiments 2 and 3 suggested further that a relatively direct structural similarity must exist between the observed and classified target patterns for the observations to be effective. When this relation was subtle or abstract, positive transfer was limited. Post experimental tests in Experiments 1 and 3 also suggested that individuals had learned something about the composition rules used to produce the target patterns rather than simple paired-associate responses. These findings have implications for pattern classification theory and for the design of performance aids for sonar technicians.

Research on auditory psychophysics has contributed surprisingly little to our understanding of how human listeners classify complex environmental sounds. This limitation is especially significant in the area of passive sonar listening. If training programs and preprocessing devices are to be designed to enhance operator performance in this task then an understanding of the psychological processes involved in the classification of such sounds is of paramount importance. The present paper describes a series of experiments which investigate how patterns of these sounds are learned.

Two broad classes of ship-produced passive sonar signatures can be identified. First, there exist steady-state signals which reflect the radiated background noise of normal ship operations. For example, the broad-band rushing sounds produced by cavitating propellers fall into this category. Second, a large class of non-steady state sounds are produced by relatively brief duration mechanical events such as hatch closings, pump operation, etc. Events of this latter type are referred to as acoustic transients (Favret, 1980). Such transient events are of particular tactical significance since they can reveal important information about the maneuvers or other actions being taken by a monitored vessel. Furthermore, the human operator often plays an important role in the identification of these sounds since their variety and short duration limit the usefulness of automatic signal processing devices for classification.

Acoustic transients frequently occur in temporal succession forming more complex <u>transient patterns</u> (Howard & Ballas, 1980).

Furthermore, since these patterns obviously mirror the physical events which produced them, the order of transient components within a pattern is not arbitrary, but rather reflects the temporal structure of the generating events. In an everyday example, one would expect to hear the garage door open before hearing the car drive out. On the other hand, a car door opening could either precede or follow the sound of the engine shutting off. Although the temporal or syntactic structure which exists in patterns of this sort is clearly less rigid and well specified than that encountered in the grammars of language, some temporal structure does exist. Previous work in our laboratory has indicated that listeners make use of their knowledge of this structure in classifying complex patterns of environmental transients (Howard & Ballas, 1980; Ballas & Howard, 1980). In several experiments listeners were required to classify transient patterns as either "targets" or "nontargets." The patterns consisted of from four to six successive environmental transients selected to resemble those encountered in a passive sonar environment. Several groups were tested. For some, the set of target patterns was produced using a simple finite-state rule structure or grammar to determine the order of pattern components. Consequently, the set of target patterns for these listeners had an underlying coherence or temporal structure. For other groups the target patterns matched the grammatical targets superficially (e.g., length, component durations, etc.), but were produced randomly and therefore lacked any systematic underlying structure. In every instance, listeners receiving grammatical target patterns performed better than listeners receiving corresponding

random or nongrammatical target patterns. In addition, individuals in the grammatical target groups were able to classify a novel set of grammatical patterns accurately following classification experience with the grammatical targets. This suggests that the listeners may have actually abstracted the target grammar during classification training rather than simply learned the category of each target pattern in a paired associate fashion.

This finding is consistent with the earlier work of Reber and his associates (Reber, 1969; Reber & Allen, 1978; Reber & Lewis, 1977) involving grammatical strings of visually presented letters. The finding that individuals correctly classified novel patterns and the further result that most participants are unable to articulate the properties of the underlying grammar in post-experimental interviews has led Reber to propose that individuals undergo an implicit learning or abstraction process in acquiring the pattern structure. He has argued that mere exposure to the structured patterns is generally sufficient to induce implicit learning "...any procedure which steeps the neutral subject in a structured environment will produce (at least partially) apprehension of that structure" (Reber & Lewis, 1977, p. 356).

Additional support for this argument has been obtained in experiments employing what Reber has referred to as the observation technique (Reber & Allen, 1978; Reber & Millward, 1968). Under this procedure individuals are presented with a series of grammatical patterns with instructions to observe or attend to the patterns carefully without making any explicit responses. Reber has shown that

participants exposed to an observation task of this sort appeared to have internalized the underlying grammar in subsequent test trials.

EXPERIMENT 1

As described previously, Reber has shown that explicit classification training is not essential for observers to internalize the rules used to produce a set of grammatical visual patterns (letter strings). In the present experiment five groups of individuals were tested to determine if a similar result occurs for auditory transient patterns. One group of participants (the sound group) classified environmental transient patterns as either "targets" or "nontargets" for 12 blocks with feedback after each response. A second group, the sound/sound group, initially "observed" or listened to a series of the target patterns played over headphones. They were told that careful attention to the sounds would make their task easier in a later part of the experiment, but they were not told that classification would be required of them until after they had completed the observation trials. After receiving 288 patterns (24 repetitions of 12 different target patterns) in a random order, they began the standard classification task. Performance of the two groups was compared to determine the effect of an observation trial relative to that of a standard classification trial.

For two other groups, the symbolic group and the symbolic/symbolic group, participants either classified or observed then classified, as in the sound and sound/sound groups. For these individuals, however, the patterns consisted of visually displayed

symbolic strings rather than auditory patterns. These symbolic patterns were sequences of words which described the environmental sounds presented to the two sound groups (e.g., "squeak"..."squeak"... "drip"...etc.). These two symbolic groups were included to compare performance under symbolic and auditory presentations.

Participants in the fifth, symbolic/sound group received 288 symbolic observation trials as described previously, but unlike the symbolic/symbolic group, the subsequent classification task for this group involved acoustic transient patterns. This transfer group was included to determine if symbolic observation trials would enable transfer to a sound classification task. On the basis of Reber's arguments (Reber, 1969) positive transfer should occur since the underlying grammatical structure remained constant, only the pattern components changed (words vs. sounds). A demonstration of symbolic-to-auditory transfer of this sort would be of practical significance. In particular, a visually-based, on-board performance or training aid could be developed which may improve sonar operator performance, but not interfere with on-going auditory monitoring.

Method

Participants. Twenty five student volunteers were paid to participate in the experiment. Five were assigned haphazardly to each of the five groups.

Stimuli. Individual transient events consisted of five brief-duration complex sounds selected from a large set of common "real-world" sounds recorded in the laboratory. The larger set was produced by recording a variety of events such as a "clank" (hammer

striking a heavy metal object), a "thump" (a hollow, resonant sound from striking a metal drum), and other similar sounds. These samples were digitized using standard signal processing techniques with a 10-bit analog-to-digital converter at a 12.5 kHz sampling rate. Five water and steam related signals were selected from this set on the basis of their general similarity to common underwater acoustic transients. Although these sounds were not actual passive sonar signatures a physical similarity did exist. A descriptive name for each of the five transients is presented in Figure 1.

Insert Figure 1 here

For the symbolic patterns the individual components consisted of the names shown in Figure 1 presented visually on a CRT display.

A set of grammatical target patterns was produced by assigning one of the five sounds to each of the output letters of the finite-state grammar shown in Figure 1. An additional component in the pattern is produced with every legal state transition made between the initial and terminal states. For example, the pattern "AAACDD" (squeak, squeak, squeak, hiss, clang, clang) could be produced by the grammar and is therefore grammatical, whereas the pattern "AADDCC" (squeak, squeak, clang, clang, hiss, hiss) would be ungrammatical since it could not be produced by the grammar. Twelve grammatical patterns ranging in length from four to six events (three, four, and five patterns of each length, respectively) were chosen to make up the target set. The same 12 target items were presented (either

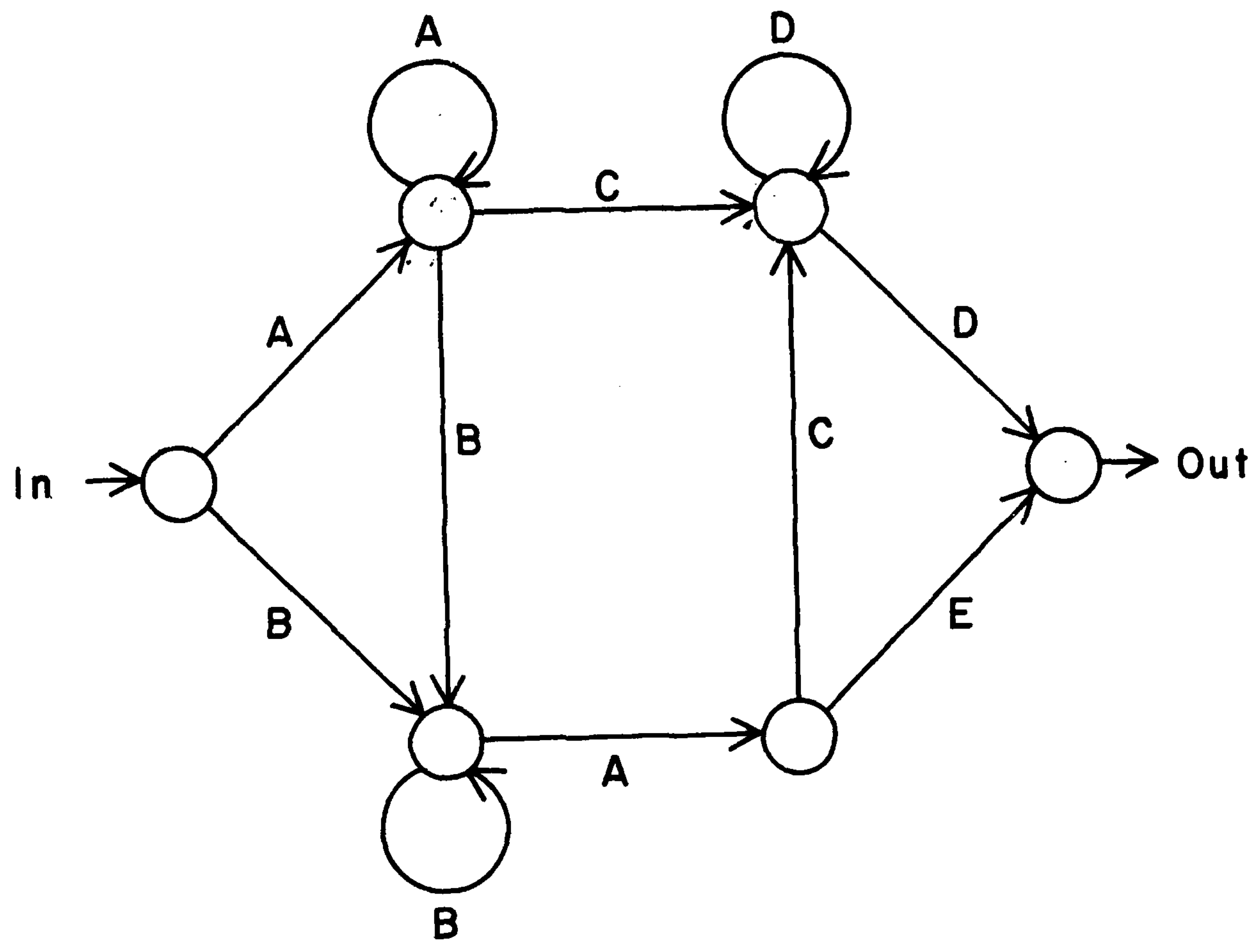

Figure 1. A state transition diagram for the finite-state grammar used to generate target patterns. The sound components assigned to the output codes were: A = valve squeak, B = water drop, C = steam hiss, D = pipe clang, E = water flush.

symbolically or acoustically) during the observation and classification trials for all five groups.

Similarly, a set of 48 randomly constructed nontarget patterns were selected for use in the classification trials. These patterns were chosen to be nonoverlapping with the target patterns, but to match them in length. For the acoustic patterns each transient was presented for a brief duration (38 ms for the drip and 320 ms for all others) at a comfortable listening level. Successive sounds were separated by 510 ms within the patterns. For the symbolic patterns transient names were presented on a CRT display with the same temporal parameters used to present the sounds. That is, the terms were displayed successively (510 ms separation) and remained in view for only a brief time (38 ms for "drip" and 320 ms for the others).

Apparatus. All the experimental events were controlled by a general-purpose laboratory computer. The acoustic patterns were output on a 12-bit digital-to-analog converter at a sampling rate of 12.5 kHz, low-pass filtered at 5 kHz (Khron-Hite Model 3550), attenuated, and presented binaurally over matched Telephonics TDH-49 headphones with MX-41/AR cushions. Testing was done individually in a sound attenuated booth and listeners indicated their responses by pressing buttons on a solid-state keyboard. The symbolic patterns were presented visually on a 30.84 cm (12 in) video monitor located approximately 1 m from the observer in the testing booth.

Procedure. All participants were read instructions explaining their task before beginning the experiment. Individuals in the observation groups were told to pay careful attention to the patterns

they would hear (see) since this "would make their task easier in a later part of the experiment." For the classification trials participants were told that they would be hearing (seeing) patterns of several items presented very quickly. They were told that some of the patterns were designated as targets and that their task would be to pick out the targets. Although the participants were told that the targets and nontargets would occur equally often, no information was provided regarding the composition of the target set. The six-point rating scale they were to use (1 = definitely a nontarget, 2 = probably a nontarget, 3 = possibly a nontarget, 4 = possibly a target, 5 = probably a target, 6 = definitely a target) was also explained at that time.

The observation trials began when the participant responded to a verbal prompt displayed on his or her screen ("PRESS ANY KEY TO BEGIN"). Trials were presented sucessively with a 2 s interval between trials. Each classification trial began when the word "LISTEN" appeared on the screen. A second response prompt (the six scale descriptors described previously) was presented immediately after the test pattern. The listener then responded by pressing a key on the keypad (a digit between "1" and "6"), and verbal feedback was presented visually following the response. After a short intertrial interval of 1.5 s, the screen was erased and the next trial began. Each block of observations consisted of 96 patterns, 8 repetitions of each of the 12 target patterns. There were also 96 trials in each classification block, four presentations of each of the 12 targets and 48 presentations of nontargets. Participants in the three observation

groups received three observation blocks (288 target presentations) followed by six classification blocks (576 trials, 288 targets and 288 nontargets). The two classification groups received 12 classification blocks (1152 trials, 576 targets and 576 nontargets). Each participant required three one-hour sessions on successive days to complete the experiment.

After the last classification block listeners in all five groups were told that the target patterns had been constructed using a set of rules -- like the rules of language. It was explained that they would be hearing a new set of patterns and that their task would be to classify each pattern using the six-point rating scale: "Just as you can tell if a sentence is grammatically correct without knowing all the rules for sentences, so should you be able to tell whether any sound is consistent with the rules we used by remembering how the targets sounded." They then completed an additional block of 96 trials as before, but without feedback. The grammatical patterns presented in this test block were produced by the grammar in Figure 1 but were not used as targets in the experiment. This test condition was included to determine whether the participants could classify novel grammatical patterns. Each participant was interviewed and debriefed before leaving.

Results and Discussion

A Receiver Operating Characteristic (ROC) was determined from the rating scale data for each participant on each block of classification trials (Green & Swets, 1966; Swets, 1979). A nonparametric, response-bias free index of performance was then computed by

determining the area under the ROC using a trapezoidal algorithm (Swets, 1979). Mean areas were determined for each group by averaging across individuals. The mean ROC area for each of the five groups was plotted by blocks in Figure 2.

Insert Figure 2 here

Several results are of interest. First, it is evident from the figure that performance improved from near chance (area of .5) to well above chance with practice for the two standard classification groups (sound and symbolic). Furthermore, performance was very similar across blocks for the two conditions. A two-way (group by block) mixed design analysis of variance (ANOVA) with repeated measures on the block factor was consistent with this observation. A significant block effect was obtained, $F(11,88) = 17.50$, $p < .001$, but neither the main effect of group, $F(1,8) < 1.0$, nor the group by block interaction, $F(11,88) < 1.0$, approached statistical significance. This result suggests that similar psychological processes may underlie pattern classification in the two groups.

The previous result is not surprising given the similar patterns and treatments used in the two groups. A more interesting result concerns the effectiveness of the observation technique for the target acquisition. Inspection of Figure 2 reveals that individuals in the three observation groups (sound/sound, symbolic/symbolic, and symbolic/sound) began their classification trials at an extremely high performance level. In particular, performance on the six

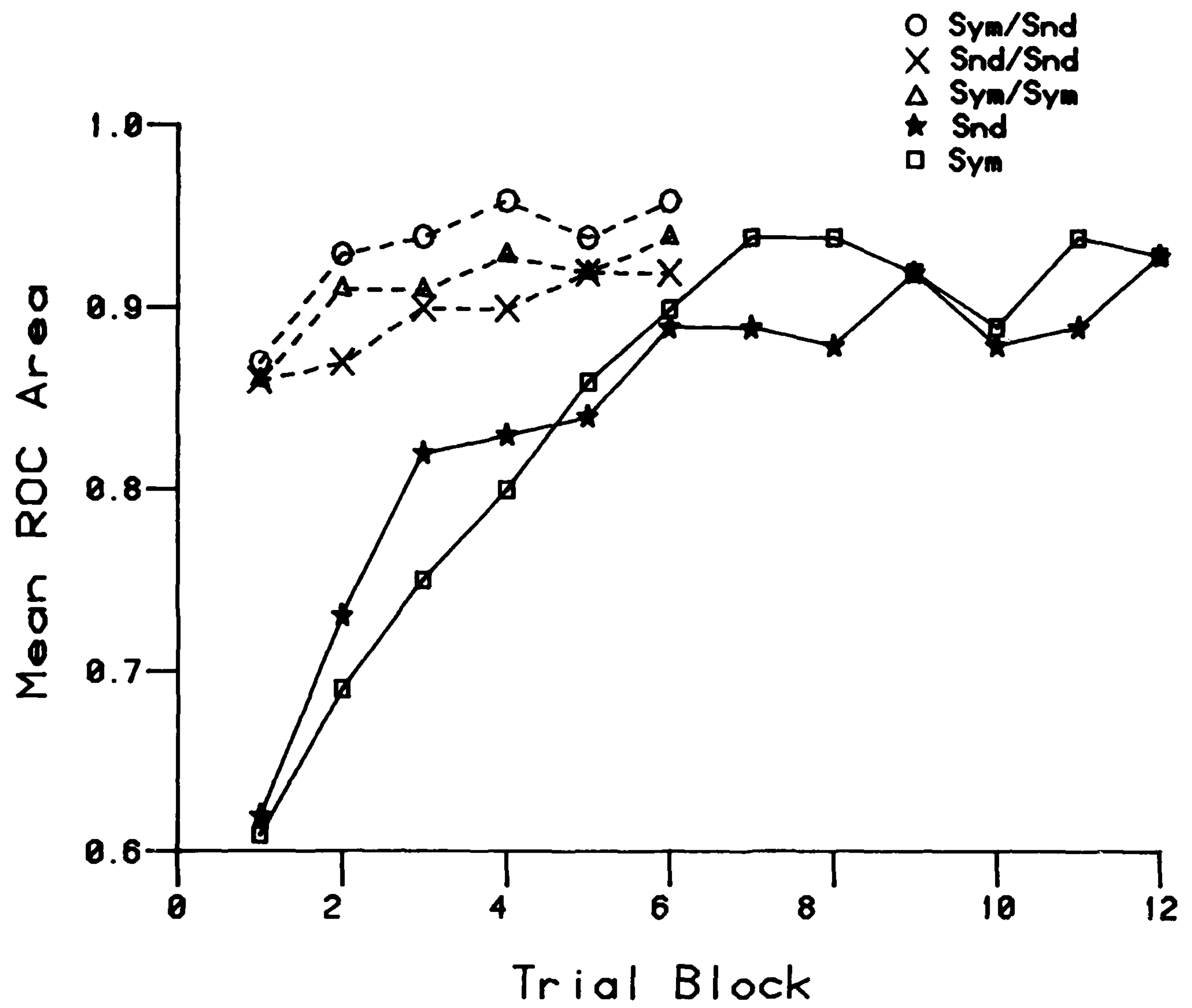

Figure 2. Mean ROC area for each of the five groups in Experiment 1 plotted as a function of trial block.

classification blocks for these individuals more closely resembled performance on the final six blocks for the standard classification groups. Two separate two-way (group by block), mixed design ANOVAs with repeated measures on the block factor were performed to compare post-observation performance to the initial and final blocks of standard classification. When the three observation groups were compared to the first six blocks of the standard groups a significant main effect of block, $F(5,100) = 22.00$, $p < .001$, and group by block interaction, $F(20,100) = 2.70$, $p < .01$, were obtained. The main effect of group did not reach statistical significance, $F(4,20) = 2.66$, $p > .05$. This indicates that initially classification performance differed reliably for the observation and standard groups, but this difference diminished across blocks. This effect is evident in Figure 2.

On the other hand, when the observation groups were compared to the final six blocks of the standard groups, neither the main effect of group, $F(4,20) < 1.0$, nor the group by block interaction, $F(20,100) = 1.45$, $p > .05$, reached statistical significance. This indicates that the six classification blocks for the observation groups were indistinguishable from the final six blocks for the standard classification groups. The main effect of block was statistically significant, $F(5,100) = 3.25$, $p < .01$, indicating that the slight tendency for improvement across these trials was reliable.

In summary, the present experiment revealed a reliable difference between the observation groups and the first six blocks for the classification groups, but no difference between the observation

groups and the last six blocks of the classification groups. Since the sound and symbolic classification groups would have received 288 target patterns and 288 nontarget patterns by the end of block six, it seems that the 288 observation trials were approximately equivalent to the 576 classification trials. In other words, one observation is worth one target classification, and the nontarget classifications appeared to contribute little in this experiment.

The symbolic/sound transfer group is of particular interest. It is evident from the analysis that positive transfer occurred between symbolic observation and auditory pattern classification. In fact, a close inspection of Figure 2 reveals that the symbolic/sound group performed at a higher level than the sound/sound group on each of the six classification blocks. The magnitude of this difference was small, however, and as indicated previously it did not reach statistical significance.

A mean performance index was also computed for each of the five groups on the post-classification test block of novel grammatical patterns. As indicated previously, this block was included to determine if individuals were able to generalize their knowledge acquired during classification to a novel set of grammatical target patterns. The mean ROC area for this test block for each of the five groups is given in Table 1.

Insert Table 1 here

Performance was reliably above chance (area = .50) for each of the

Table 1

Mean ROC Area for Test Block of

Novel Grammatical Patterns for

Each of the Five Groups in Experiment 1

Group	Mean ROC Area
Sound	.875*
Symbolic	.869*
Sound/Sound	.794*
Symbolic/Symbolic	.814*
Symbolic/Sound	.895*

* $p < .01$

five groups as determined by independent _t_ tests, and there was no evidence of any difference between the observation and standard classification groups.

EXPERIMENT 2

Overall, the results of Experiment 1 demonstrated that observation, and in particular _symbolic_ observation can be an effective technique for target acquisition in a structured acoustic pattern classificaton task. Two possible explanations exist for this result. First, it is possible--as Reber would argue--that participants were able to abstract the underlying pattern structure or grammar implicitly during the observation trials. This explanation would account for the positive transfer obtained for the symbolic/sound group. Since individuals were apprehending some abstract rule system during the observations, it should not matter how the rules were presented. That is, symbolic patterns would be as effective as the actual acoustic patterns (Reber, 1969). The finding that participants could generalize their post-classification knowledge to identify novel grammatical patterns reliably is also consistent with this interpretation. It is also possible, however, that grammar apprehension during classification rather than observation accounts for the latter result.

Second, participants in Experiment 1 may have learned something much more concrete during the observation trials. In particular, individuals in the symbolic/sound transfer group may have employed an explicit translation strategy in which the acoustic patterns presented

during classification were first translated into a verbal code before a categorization was made. According to this explanation positive transfer would only occur when a direct relation exists between the patterns presented during observation and those presented during classification. In other words, the individuals must recognize that the classification target set could be translated into the observation target set or vice-versa. This translatability criterion was met in each of the observation conditions examined in Experiment 1.

Experiment 2 was designed to investigate these two major possibilities further. Specifically, an additional observation group (the tone/sound group) was tested in which the patterns presented during observations were made up of pure tones and those presented during classification were made up of the complex environmental sounds described previously. In both cases the tonal patterns and the sound patterns were generated by the finite-state grammar used in Experiment 1. If positive transfer is obtained in this experiment then the first of the above hypotheses would be supported. Since the same pattern grammar is used for the observation and classification trials, participants should be able to abstract the appropriate pattern grammar during the observations. On the other hand, if positive transfer is not obtained then the second alternative would be supported. This explanation assumes that individuals notice the translatability of the observation and classification targets. If the similarity of the two target sets is not obvious then the participants would not adopt the translation strategy and positive transfer would not occur.

Method

Participants. Five student volunteers were paid to participate in the experiment. None of these individuals had participated in Experiment 1.

Stimuli. The target patterns used for observation matched those employed in Experiment 1, but pure tones rather than complex environmental sounds were used as pattern components. The tones were selected to be approximately equally spaced in pitch (1157, 1250, 1345, 1442, and 1542 Hz). The acoustic patterns presented during the six classification blocks were identical to those used in Experiment 1.

Apparatus. The apparatus was identical to that used in Experiment 1.

Procedure. The procedure was identical to that used for the observation groups in Experiment 1.

Results and Discussion

A nonparametric, response-bias free index of performance was determined for each individual on each block as described previously. The mean ROC area computed for each of the six classificaton blocks for the tone/sound group is presented in Figure 3 together with the three sound classification groups from Experiment 1 (sound/sound, symbolic/sound, and standard sound classification).

Insert Figure 3 here

Inspection of these data suggests that the present tone/sound

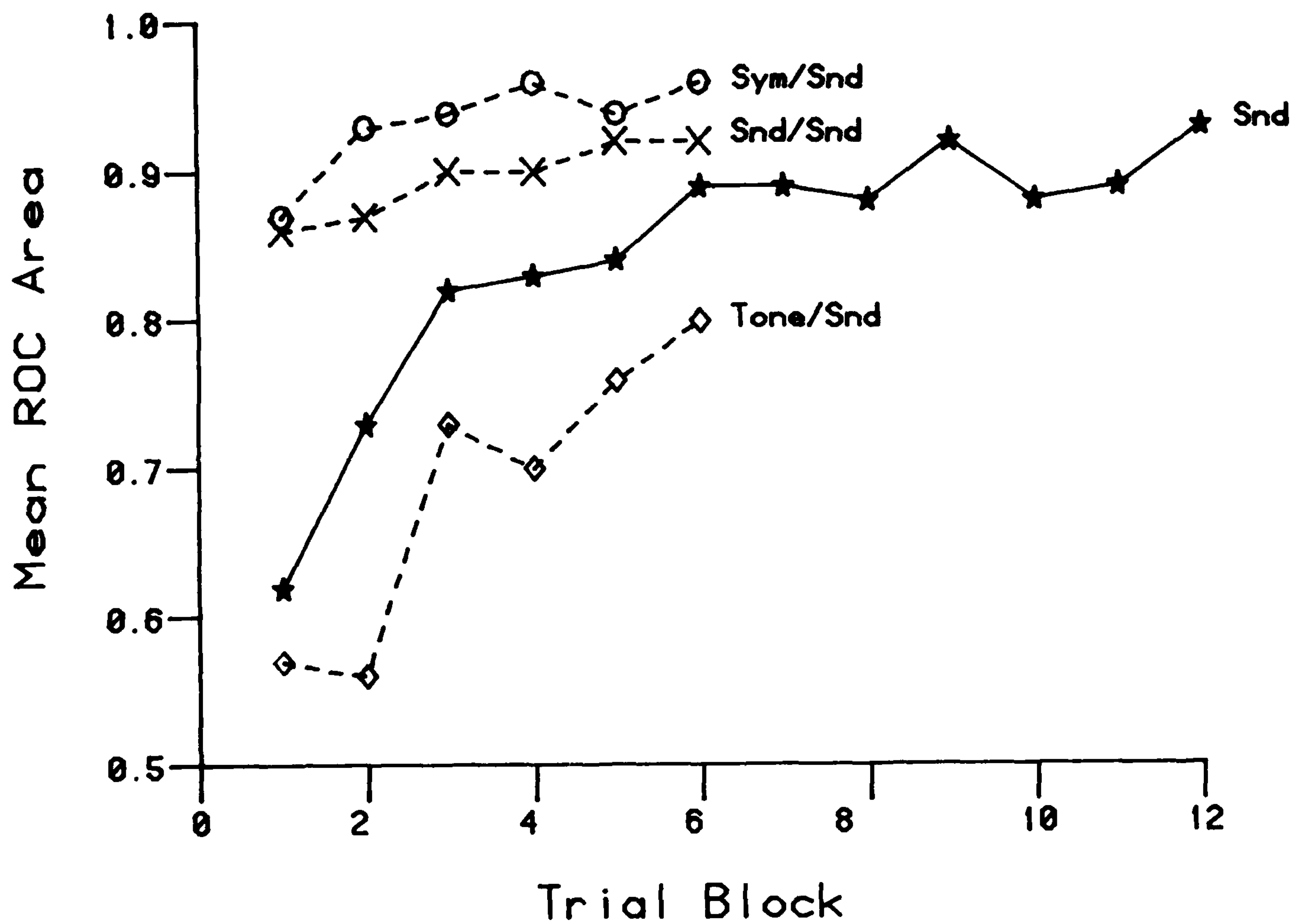

Figure 3. Mean ROC area for the tone/sound group tested in Experiment 2 compared with the three sound classification groups from Experiment 1.

transfer group more nearly approximates the initial performance of the standard sound classification group than the performance of either observation group (sound/sound and symbolic/sound). This possibility was examined statistically in two, two-way (group by block), mixed-design ANOVAs with repeated measures on the block factor. The first compared the three observation groups shown in Figure 3, whereas the second compared the present tone/sound group to the initial six blocks of the standard sound classification group.

The first ANOVA revealed a large overall difference between the three observation groups, $F(2,12) = 8.41$, $p < .025$, as well as a significant main effect of block, $F(5,60) = 15.29$, $p < .001$, and a significant block by group interaction, $F(10,60) = 4.29$, $p < .001$. The source of these effects is obvious in Figure 3. Overall performance was substantially worse for the tone/sound group (mean area = .69) than for the sound/sound and symbolic/sound groups (mean areas = .90 and .93, respectively). Furthermore, a relatively large improvement in performance occurred over blocks for the tone/sound group whereas only a relatively slight improvement can be noted for the other two observation groups. This result suggests that little or no positive transfer occurred for the tone/sound group.

This interpretation was substantiated further in the second ANOVA comparing the tone/sound and sound groups. Neither the main effect of group, $F(1,8) = 2.34$, $p > .10$, nor the group by block interaction, $F(5,40) < 1.00$, reached statistical significance. The main effect of block, $F(5,40) = 18.83$, $p < .001$, was reliable. This indicates a high degree of similarity between the two groups. Since the straight

classification group had no observation training before beginning classification, this suggests that the tonal patterns observed in the present experiment were totally ineffective for target acquisition. In fact, although the tone/sound and sound groups did not differ significantly, it is interesting to note that the tone/sound groups performed more poorly than the sound group on each of the six classification blocks. This suggests that some negative transfer may be present.

Participant performance on the post-classification test block was also examined for this group. Surprisingly, these individuals were able to identify novel grammatical sound patterns significantly better than chance (mean area = .703, $\underline{t}(4) = 3.42$, $\underline{p} < .02$) despite their poor performance on the classification trials. It is likely that pattern generalization occurred because of their classification experience rather than the combined observation/classification experience.

EXPERIMENT 3

It is clear from Experiment 2 that positive transfer did not occur for the tone/sound transfer group even though the same pattern grammar was used for the observation and classification target sets. There are two primary explanations for this result. First, as suggested previously, it is possible that an obvious relation must exist between the observed and classified target patterns. Once this relation was noticed the participant could employ some sort of explicit translation strategy during the classification trials. Since

in Experiment 2 the tonal patterns were not obviously related to the environmental sound patterns, individuals in the tone/sound group may not have adopted this strategy. Second, it is possible that Reber's implicit structural learning processes did not occur for the pure tone patterns presented during the observation trials. This latter alternative seems unlikely *a priori* since previous work has demonstrated pattern learning for similarly abstract patterns of light onsets (Reber & Millward, 1968). Nevertheless, both alternatives are examined in Experiment 3.

Two additional observation/classification transfer groups were tested in this experiment. Individuals in both groups initially observed a series of pure tone patterns as in the tone/sound group. However, unlike the tone/sound group, tonal patterns were also used during the subsequent classification trials for these participants. The observation patterns were constructed from components in the 500-815 Hz range, whereas the classification patterns were made up of components in a higher frequency region, 920-1500 Hz. For the consistent group, the target patterns used in classification had the same pitch envelope as those presented during observation. In other words, the classification targets were simply the observation targets shifted upward in pitch. For these individuals the relation between the classification targets and observation targets should be apparent. On the other hand, for the inconsistent group the classification targets--although grammatically identical to the observation patterns--did not have the same pitch envelope as the observation patterns. In this case the five higher frequency tones were assigned

to the grammatical output codes (see Figure 1) in a random order. Consequently, the relation between the classification and observation tasks should be less obvious for these individuals.

If, as suggested by the first of the hypotheses outlined previously, listeners must explicitly notice the relation between the two tasks for positive transfer to occur, then listeners in the consistent group should respond at a higher level than those in the inconsistent group. If, on the other hand, the second hypothesis is correct then positive transfer should not occur for either group since pure tone patterns are used in both cases.

Method

Participants. Ten student volunteers were paid to participate in the experiment. Five were assigned haphazardly to each group.

Stimuli. The observation patterns were generated using the finite-state grammar shown in Figure 1 with five pure tones selected to be approximately equally spaced in pitch (500, 565, 638, 721, and 815 Hz). The target and nontarget patterns used in classification were produced as in Experiment 1, but with pure tones equally spaced in pitch as target components (920, 1040, 1175, 1327, and 1500 Hz). The five low-frequency tones were assigned randomly to the grammatical output codes shown in Figure 1 for the observation patterns (D, A, E, B, C for the five tones, respectively). This same ordinal assignment was employed to generate the classification target patterns for the consistent group, whereas a different random assignment was used for the inconsistent group (E, B, A, C, D for the five high-frequency tones, respectively).

Apparatus. Identical to Experiments 1 and 2.

Procedure. Identical to Experiment 2, however, no post-classification test block was administered.

Results and Discussion

A nonparametric, response-bias free index of performance was determined for each individual on each block as described previously. The mean ROC area was computed for each of the six classification blocks for both groups. These data are presented in Figure 4.

Insert Figure 4 here

These data were examined in a two-way (group by block), mixed-design ANOVA with repeated measures on the block factor. The analysis revealed a significant main effect of block, $F(5,40) = 12.87$, $p < .001$, and block by group interaction, $F(5,40) = 2.97$, $p < .025$; however, the main effect of group did not approach statistical significance, $F(1,8) < 1.0$. At first glance these findings appear inconsistent with either of the two hypotheses under consideration. It is evident from Figure 4 that both groups performed at a fairly high level (mean ROC areas of .83 and .84 for the consistent and inconsistent groups, respectively), substantially better than that observed for the tone/sound group tested in Experiment 2 (mean ROC area of .69). This suggests that some positive transfer did occur for both groups in the present experiment, ruling out the second hypothesis.

On the other hand, no overall difference was obtained between the

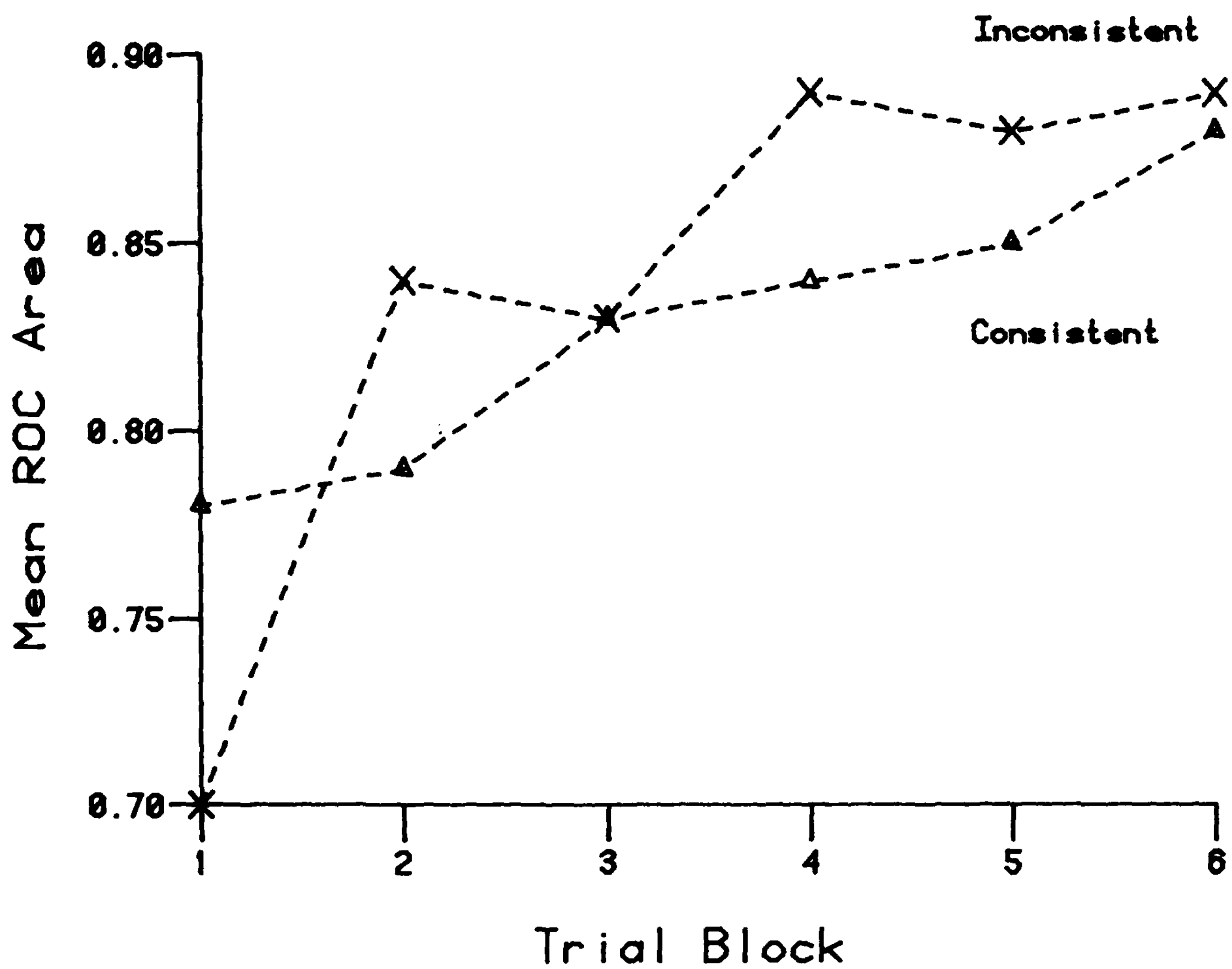

Figure 4. Mean ROC area for each of the six classification blocks for both groups in Experiment 3.

two groups as suggested by the first, explicit translation hypothesis. However, a closer examination of Figure 4 suggests that the two groups did differ initially with the consistent group outperforming the inconsistent group on the first classification block (mean areas of .78 and .70, respectively). This interpretation was supported in a post hoc analysis of the simple effects of group within blocks (Lindquist's test, critical difference = .06). This finding offers partial support for the explicit translation hypothesis. Individuals in the consistent group readily noticed the relation between the observation and classification patterns and adopted an appropriate response strategy from the outset. In contrast, individuals in the inconsistent group required additional time to notice the correspondence and consequently began classification at a lower performance level.

It is of further interest to compare the amount of positive transfer obtained in the present experiment with that obtained for the three observation groups in Experiment 1. Each of the observation groups of Experiment 1 began classification at a higher performance level than did either of the present groups (mean areas of .86, .87, and .86 for the sound/sound, symbolic/sound and symbolic/symbolic groups, respectively). This result is consistent with the previous finding that interpretable patterns of environmental sounds are more easily learned than are semantically-barren patterns of pure tones (Howard & Ballas, 1980).

GENERAL DISCUSSION

A number of findings are of interest in the present study. First, the observation technique was shown effective for the acquisition of structured acoustic transient patterns. This occurred for both pure tone pattern components in Experiment 3 and complex environmental sound components in Experiment 1. In addition, participants in the symbolic/sound group of Experiment 1 were able to transfer their knowledge of symbolic, visually-presented observation patterns to an acoustic-transient pattern-classification task. The present findings also indicate that a relatively direct relation should exist between the observed patterns and the patterns presented during classification if positive transfer is to occur. Two findings justify this conclusion. First, individuals in the tone/sound group of Experiment 2 revealed no positive transfer from observation to classification even though the pure tone patterns presented in observation were structurally identical to the environmental sound patterns used in classification. Second, participants in Experiment 3 began classification at a higher performance level when a more direct relation existed between the observed and classified patterns. These findings are of both practical and theoretical significance.

As suggested previously, the demonstration that the observation technique is effective for acoustic pattern acquisition has potential applications in passive sonar. Specifically, since observation trials are based exclusively on the presentation of positive exemplars of the target category (i.e., nontargets are not presented) and no explicit responding is required, observation trials can be presented more

quickly and efficiently than can traditional classification trials. Consequently, observations may be useful in the training of sonar operators or in the development of a ship-board aid to maintain the classification skills of experienced operators at an optimal level. Experience of this sort would be especially useful for important, but infrequent target categories. Tape libraries of these significant patterns could be developed for periodic "observations."

The further finding that positive transfer occurred from symbolic observation to acoustic classification indicates that the performance aid need not be acoustically based. If adequate verbal descriptions could be developed for significant sonar patterns then these descriptions may also be effective in maintaining operator performance. As in the present study, the symbolic patterns could be presented to operators on a CRT display with target exemplars conveniently stored on diskette libraries for microprocessor access. The advantage of this procedure over direct acoustic presentation is the possibility that symbolic observations could occur concurrently with routine acoustic monitoring without interference. Further research should investigate this possibility.

In addition to their practical implications, the present findings are of theoretical interest as well. In particular, Reber has argued that participants implicitly learn the underlying rules used to generate the patterns (Reber & Lewis, 1977). Since individuals in the present study were able to classify novel grammatical patterns accurately in a post-classification test block, the present findings are generally consistent with Reber's conclusion. Nevertheless, an

important constraint should be placed on this interpretation on the basis of our findings. It appears that a relatively direct relation must exist between the observed and classified target patterns for the observation technique to be effective. When the targets in classification were not obviously related to the observation patterns (tone/sound group of Experiment 2), positive transfer did not occur. Similarly, initial classification performance was poorer for the inconsistent group than for the consistent group in Experiment 3. The relation between the observation and classification tasks was less obvious for individuals in the former, inconsistent group.

Since Reber (Reber & Lewis, 1977) assumes that individuals learn an abstract structure rather than concrete pattern instances during observation, positive transfer should occur across structurally similar patterns regardless of their overt similarity. Although the present findings are not consistent with this, Reber's interpretation cannot be ruled out. It is possible, for example, that individuals in the present study learned the underlying pattern grammar during observation, but that they did not apply this knowledge to the classification task because the apparent differences between the two sets of patterns were large. This possibility was articulated in a preceding section as the "translation hypothesis." The remarks made by individuals in Experiments 2 and 3 in the post-experimental interview are of particular interest in this context. Curiously, no one in either the consistent or inconsistent group seemed to notice the relation between the low-frequency tonal patterns presented in observation and the high-frequency tonal patterns used in

classification. Despite this, both groups ultimately showed positive transfer across the two tasks! This raises the possibility that any translation process that occurs may be implicit rather than explicit.

Another point of general theoretical interest concerns the overall effectiveness of the observation technique for acoustic target acquisition. Since negative instances or nontargets are never presented during these trials, it is obvious that they are not essential for learning to occur. Previous work on conceptual learning has suggested that negative instances may be particularly important (Smoke, 1933; Winston, 1973). For example, Winston (1973) proposed that "near misses" or negative concept instances which are similar to positive exemplars play an important role in concept attainment. Without this experience participants may overgeneralize the concept or incorrectly identify some negative instances as targets. Future work should explore this possibility further and investigate the effect of presenting nontarget as well as target patterns during the observation trials.

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